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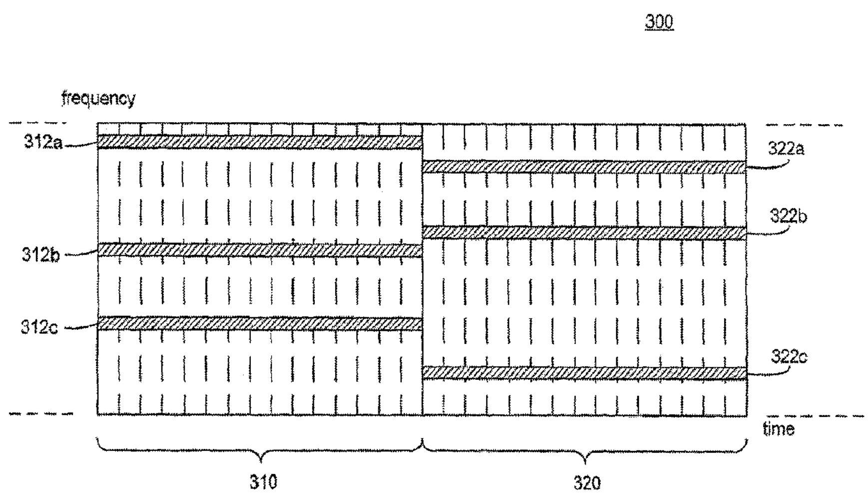
[Continued on next page]

(54) Title: SHARED SIGNALING CHANNEL



(57) **Abstract:** A shared signaling channel can be used in an Orthogonal Frequency Division Multiple Access (OFDMA) communication system to provide signaling, acknowledgement, and power control messages to access terminals within the system. The shared signaling channel can be assigned to a predetermined number of sub-carriers within any frame. The assignment of a predetermined number of sub-carriers to the shared signaling channel establishes a fixed bandwidth overhead for the channel. The actual sub-carriers assigned to the channel can be varied periodically, and can vary according to a predetermined frequency hopping schedule. The amount of signal power allocated to the signaling channel can vary on a per symbol basis depending on the power requirements of the communication link. The shared signaling channel can direct each message carried on the channel to one or more access terminals. Unicast messages allow the channel power to be controlled per the needs of individual communication links.

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SHARED SIGNALING CHANNEL

BACKGROUND

Field of the Disclosure

[0001] The disclosure relates to the field of wireless communications. More particularly, the disclosure relates to a shared signaling channel in a wireless communication system.

Description of Related Art

[0004] Wireless communication systems can be configured as multiple access communication systems. In such systems, the communication system can concurrently support multiple users across a predefined set of resources. Communication devices can establish a link in the communication system by requesting access and receiving an access grant.

[0005] The resources the wireless communication system grants to the requesting communication device depends, largely, on the type of multiple access system implemented. For example, multiple access systems can allocate resources on the basis of time, frequency, code space, or some combination of factors.

[0006] The wireless communication system needs to communicate the allocated resources and track them to ensure that two or more communication devices are not allocated overlapping resources, such that the communication links to the communication devices are not degraded. Additionally, the wireless communication system needs to track the allocated resources in order to track the resources that are released or otherwise available when a communication link is terminated.

[0007] The wireless communication system typically allocates resources to communication devices and the corresponding communication links in a centralized manner, such as from a centralized communication device. The resources allocated, and in some cases de-allocated, need to be communicated to the communication devices. Typically, the wireless communication system dedicates one or more communication channels for the transmission of the resource allocation and associated overhead.

[0008] However, the amount of resources allocated to the overhead channels typically detracts from the resources and corresponding capacity of the wireless communication system. Resource allocation is an important aspect of the communication system and care needs to be taken to ensure that the channels allocated to resource allocation are robust. However, the wireless communication system needs to balance the need for a robust resource allocation channel with the need to minimize the adverse effects on the communication channels.

[0009] It is desirable to configure resource allocation channels that provide robust communications, yet introduce minimal degradation of system performance.

BRIEF SUMMARY

[0010] A shared signaling channel can be used in a wireless communication system to provide signaling messages to access terminals within the system. The shared signaling channel can be assigned to a predetermined number of sub-carriers within any frame. The assignment of a predetermined number of sub-carriers to the shared signaling channel establishes a fixed bandwidth overhead for the channel. The actual sub-carriers assigned to the channel can be varied periodically, and can vary according to a predetermined frequency hopping schedule. The amount of signal power allocated to the signaling channel can vary on a per symbol basis depending on the power requirements of the communication link. The shared signaling channel can direct each message carried on the channel to one or more access terminals. Unicast or otherwise directed messages allow the channel power to be controlled per the needs of individual communication links.

[0011] The disclosure includes a method of generating signaling channel messages in a wireless communication system including a plurality of sub-carriers spanning at least a portion of an operating frequency band. The method includes assigning resources corresponding to a predetermined bandwidth allocated to a signaling channel, generating at least one message, encoding the at least one message to generate at least one message symbol, controlling a power density of the at least one message symbol, and modulating at least a portion of the resources allocated to the signaling channel.

[0012] The disclosure also includes a method that includes generating at least one message, encoding the at least one message to generate a plurality of message symbols, adjusting a power density associated with the plurality of message symbols, determining a subset of sub-carriers assigned to a signaling channel from the plurality of sub-carriers, and modulating each of the subset of sub-carriers with at least one symbol from the plurality of message symbols.

[0013] The disclosure includes an apparatus configured to generate signaling channel messages in a wireless communication system including a plurality of sub-carriers spanning an operating frequency band. The apparatus includes a scheduler configured to assign a subset of the plurality of sub-carriers to a signaling channel, a signaling module configured to generate at least one signaling message, a power control module configured to adjust a power density of the at least one signaling message, and a signal mapper coupled to the scheduler and the signaling module and configured to map symbols from the at least one signaling message to the subset of the plurality of sub-carriers.

[0014] The disclosure includes an apparatus that includes means for generating at least one message, means for encoding the at least one message to generate a plurality of message symbols, means for adjusting a power density associated with the plurality of message symbols, means for determining a subset of sub-carriers assigned to a signaling channel from the plurality of sub-carriers, and means for modulating each of the subset of sub-carriers with at least one symbol from the plurality of message symbols.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The features, objects, and advantages of embodiments of the disclosure will become more apparent from the detailed description set forth below when taken in conjunction with the drawings, in which like elements bear like reference numerals.

[0016] Figure 1 is a simplified functional block diagram of an embodiment of a communication system having a shared signaling channel.

[0017] Figure 2 is a simplified functional block diagram of an embodiment of a transmitter supporting a shared signaling channel.

[0018] Figure 3 is a simplified time-frequency diagram of an embodiment of a shared signaling channel.

[0019] Figure 4 is a simplified flowchart of an embodiment of a method of generating shared signaling channel messages.

[0020] Figure 5 is a simplified flowchart of an embodiment of a method of generating shared signaling channel messages.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0021] A shared signaling channel (SSCH) in an OFDMA wireless communication system can be used to communicate various signaling and feedback messages implemented within the system. The wireless communication system can implement a SSCH as one of a plurality of forward link communication channels. The SSCH can be simultaneously or concurrently shared among a plurality of access terminals within the communication system.

[0022] The wireless communication system can communicate various signaling messages in a forward link SSCH. For example, the wireless communication system can include access grant messages, forward link assignment messages, reverse link assignment messages, as well as any other signaling messages that may be communicated on a forward link channel. The SSCH can also be used to communicate feedback messages to access terminals. The feedback messages can include acknowledgement (ACK) messages confirming successful receipt of access terminal transmissions. The feedback messages can also include reverse link power control messages that are used to instruct a transmitting access terminal to vary its transmit power.

[0023] The actual channels utilized in an SSCH may be all or some of the ones described above. Additionally, other channels may be included in SSCH in addition or in lieu of, any of the above channels.

[0024] The wireless communication system can allocate a predetermined number of sub-carriers to the SSCH. Assigning a predetermined number of sub-carriers to the SSCH establishes a fixed bandwidth overhead for the channel. The actual sub-carriers

assigned to the SSCH can be varied periodically, and can vary according to a predetermined frequency hopping schedule. In one embodiment, the identity of the sub-carriers assigned to the SSCH can vary across each frame.

[0025] The amount of power that is allocated to the SSCH can vary depending on the requirements of the communication link carrying the SSCH message. For example, the SSCH power can be increased when the SSCH messages are transmitted to a distant access terminal. Conversely, the SSCH power can be decreased when the SSCH messages are transmitted to a nearby access terminal. If there is no SSCH message to be transmitted, the SSCH need not be allocated any power. Because the power allocated to the SSCH can be varied on a per user basis when unicast messaging is implemented, the SSCH requires a relatively low power overhead. The power allocated to the SSCH increases only as needed by the particular communication link.

[0026] The amount of interference that the SSCH contributes to the data channels for the various access terminals can vary based on the sub-carriers assigned to the SSCH and the access terminals, as well as the relative power levels of the SSCH and the data channels. The SSCH contributes substantially no interference for many communication links.

[0027] Figure 1 is a simplified functional block diagram of an embodiment of a wireless communication system 100 implementing a SSCH on the forward link. The system 100 includes one or more fixed elements that can be in communication with one or more access terminals 110a-110b. Although the description of the system 100 of Figure 1 generally describes a wireless telephone system or a wireless data communication system, the system 100 is not limited to implementation as a wireless telephone system or a wireless data communication system nor is the system 100 limited to having the particular elements shown in Figure 1.

[0028] Each access terminal 110a-110b can be, for example, a wireless telephone configured to operate according to one or more communication standards. An access terminal 110a can be a portable unit, a mobile unit, or, a stationary unit. Each of the access terminals 110a-110b may also be referred to as a mobile unit, a mobile terminal, a mobile station, a user terminal, user equipment, a portable, a phone, and the like. Although only a two access terminals 110a-110b are shown in Figure 1, it is understood

that a typical wireless communication system 100 has the ability to communicate with multiple access terminals 110a-110b.

[0029] An access terminal 110a typically communicates with one or more base stations 120a or 120b, here depicted as sectored cellular towers. Other embodiments of the system 100 may include access points in place of the base stations 120a and 120b. In such a system 100 embodiment, the BSC 130 and MSC 140 may be omitted and may be replaced with one or more switches, hubs, or routers.

[0030] As used herein, a base station may be a fixed station used for communicating with the terminals and may also be referred to as, and include some or all the functionality of, an access point, a Node B, or some other terminology. An access terminal may also be referred to as, and include some or all the functionality of, a user equipment (UE), a wireless communication device, terminal, a mobile station or some other terminology.

[0031] The access terminal 110a will typically communicate with the base station, for example 120b that provides the strongest signal strength at a receiver within the access terminal 110a. A second access terminal 110b can also be configured to communicate with the same base station 120b. However, the second access terminal 110b may be distant from the base station 120b, and may be on the edge of a coverage area served by the base station 120b.

[0032] The one or more base stations 120a-120b can be configured to schedule the channel resources used in the forward link, reverse link, or both links. Each base station, 120a-120b, can communicate sub-carrier assignments, acknowledgement messages, reverse link power control messages, and other overhead messages using the SSCH.

[0033] Each of the base stations 120a and 120b can be coupled to a Base Station Controller (BSC) 140 that routes the communication signals to and from the appropriate base stations 120a and 120b. The BSC 140 is coupled to a Mobile Switching Center (MSC) 150 that can be configured to operate as an interface between the access terminals 110a-110b and a Public Switched Telephone Network (PSTN) 150. In another embodiment, the system 100 can implement a Packet Data Serving Node (PDSN) in place or in addition to the PSTN 150. The PDSN can operate to interface a

packet switched network, such as network 160, with the wireless portion of the system 100.

[0034] The MSC 150 can also be configured to operate as an interface between the access terminals 110a-110b and a network 160. The network 160 can be, for example, a Local Area Network (LAN) or a Wide Area Network (WAN). In one embodiment, the network 160 includes the Internet. Therefore, the MSC 150 is coupled to the PSTN 150 and network 160. The MSC 150 can also be configured to coordinate inter-system handoffs with other communication systems (not shown).

[0035] The wireless communication system 100 can be configured as an OFDMA system with communications in both the forward link and reverse link utilizing OFDM communications. The term forward link refers to the communication link from the base stations 120a or 120b to the access terminals 110a-110b, and the term reverse link refers to the communication link from the access terminals 110a-110b to the base stations 120a or 120b. Both the base stations 120a and 120b and the access terminals 110a-110b may allocate resources for channel and interference estimation.

[0036] The base stations, 120a and 120b, and the access terminal 110 can be configured to broadcast a pilot signal for purposes of channel and interference estimation. The pilot signal can include broadband pilots such as a plurality of CDMA waveforms or a collection of narrow band pilots that span the overall spectrum. The broadband pilots could also be a collection of narrow band pilots staggered in time and frequency.

[0037] In one embodiment, the pilot signal can include a number of tones selected from the OFDM frequency set. For example, the pilot signal can be formed from uniformly spaced tones selected from the OFDM frequency set. The uniformly spaced configuration may be referred to as a staggered pilot signal.

[0038] The wireless communication system 100 can include a set of sub-carriers, alternatively referred to as tones that span an operating bandwidth of the OFDMA system. Typically, the sub-carriers are equally spaced. The wireless communication system 100 may allocate one or more sub-carriers as guard bands, and the system 100 may not utilize the sub-carriers within the guard bands for communications with the access terminals 110a-110b.

[0039] In one embodiment, the wireless communication system 100 can include 2048 sub-carriers spanning an operating frequency band of 20 MHz. A guard band having a bandwidth substantially equal to the bandwidth occupied by one or more sub-carriers can be allocated on each end of the operating band.

[0040] The wireless communication system 100 can be configured to Frequency Division Duplex (FDD) the forward and reverse links. In a FDD embodiment, the forward link is frequency offset from the reverse link. Therefore, forward link sub-carriers are frequency offset from the reverse link sub-carriers. Typically, the frequency offset is fixed, such that the forward link channels are separated from the reverse link sub-carriers by a predetermined frequency offset. The forward link and reverse link may communicate simultaneously, or concurrently, using FDD.

[0041] In another embodiment, the wireless communication system 100 can be configured to Time Division Duplex (TDD) the forward and reverse links. In such an embodiment, the forward link and reverse links can share the same sub-carriers, and the wireless communication system 100 can alternate between forward and reverse link communications over predetermined time intervals. In TDD, the allocated frequency channels are identical between the forward and reverse links, but the times allocated to the forward and reverse links are distinct. A channel estimate performed on a forward or reverse link channel is typically accurate for the complementary reverse or forward link channel because of reciprocity.

[0042] The wireless communication system 100 can also implement an interlacing format in one or both the forward and reverse links. Interlacing is a form of time division multiplexing in which the communication link timing is cyclically assigned to one of a predetermined number of interlace periods. A particular communication link to one of the access terminals, for example 110a, can be assigned to one of the interlace periods, and communications over the particular assigned communication link occurs only during the assigned interlace period. For example, the wireless communication system 100 can implement an interlace period of six. Each interlace period, identified 1-6, has a predetermined duration. Each interlace period occur periodically with a period of six. Thus, a communication link assigned to a particular interlace period is active once every six periods.

[0043] Interlaced communications are particularly useful in wireless communication systems 100 implementing an automatic repeat request architecture, such as a Hybrid Automatic Repeat Request (HARQ) algorithm. The wireless communication system 100 can implement a HARQ architecture to process data retransmission. In such a system, a transmitter may send an initial transmission at a first data rate and may automatically retransmit the data if no acknowledgement message is received. The transmitter can send subsequent retransmissions at lower data rates. HARQ incremental redundancy retransmission schemes can improve system performance in terms of providing early termination gain and robustness.

[0044] The interlace format allows sufficient time for processing of the ACK messages prior to the next occurring assigned interlace period. For example, an access terminal 110a can receive transmitted data and transmit an acknowledgement message, and a base station 120b can receive and process the acknowledgement message in time to prevent retransmission at the next occurring interlace period. Alternatively, if the base station 120b fails to receive the ACK message, the base station 120b can retransmit the data at the next occurring interlace period assigned to the access terminal 110a.

[0045] The base stations 120a-120b can transmit the SSCH messages in each interlace, but may limit the messages occurring in each interlace to those messages intended for access terminals 110a-110b assigned to that particular active interlace. The base stations 120a-120b can limit the amount of SSCH messages that need to be scheduled in each interlace period.

[0046] The wireless communication system 100 can implement a Frequency Division Multiplex (FDM) SSCH in the forward link for the communication of signaling and feedback messages. Each base station 120a-120b can allocate a predetermined number of sub-carriers to the SSCH. The wireless communication system 100 can be configured to allocate a fixed bandwidth overhead to the SSCH. Each base station 120a-120b can allocate a predetermined percentage of its sub-carriers to the SSCH. Additionally, each base station 120a or 120b may allocate a different set of sub-carriers to the SSCH or the set of sub-carriers may overlap the SSCH sub-carrier assignment of another base station. For example, each base station 120a or 120b can be configured to allocate approximately 10% of the bandwidth to the SSCH. Thus, in a wireless

communication system 100 having up to 2000 sub-carriers that can be allocated to the SSCH, each base station 120a or 120b allocates 200 sub-carriers to the SSCH. Of course other wireless communication systems 100 can be configured with other bandwidth overhead targets. For example, the wireless communication system 100 can have a target SSCH bandwidth allocation that is 2%, 5%, 7%, 15%, 20% or some other number, based on the projected channel loading.

[0047] Each base station, for example 120b, can allocate a plurality of nodes from a channel tree to the SSCH. The channel tree is a channel model that can include a plurality of branches that eventually terminate in leaf or base nodes. Each node in the tree can be labeled, and each node identifies every node and base node beneath it. A leaf or base node of the tree can correspond to the smallest assignable resource, such as a single sub-carrier. Thus, the channel tree provides a logical map for assigning and tracking the available sub-carrier resources in the wireless communication system 100.

[0048] The base station 120b can map the nodes from the channel tree to physical sub-carriers used in the forward and reverse links. For example, the base station 120b can allocate a predetermined number of resources to the SSCH by assigning a corresponding number of base nodes from a channel tree to the SSCH. The base station 120b can map the logical node assignment to a physical sub-carrier assignment that ultimately is transmitted by base station 120b.

[0049] It may be advantageous to use the logical channel tree structure or some other logical structure to track the resources assigned to the SSCH when the physical sub-carrier assignments can change. For example, the base stations 120a-120b can implement a frequency hopping algorithm for the SSCH as well as other channels, such as data channels. The base stations 120a-120b can implement a pseudorandom frequency hopping scheme for each assigned sub-carrier. The base stations 120a-120b can use the frequency hopping algorithm to map the logical nodes from the channel tree to corresponding physical sub-carrier assignments.

[0050] The frequency hopping algorithm can perform frequency hopping on a symbol basis or a block basis. Symbol rate frequency hopping can frequency hop each individual sub-carrier distinct from any other sub-carrier, except that no two node are assigned to the same physical sub-carrier. In block hopping, a contiguous block of sub-

carriers can be configured to frequency hop in a manner that maintains the contiguous block structure. In terms of the channel tree, a branch node that is higher than a leaf node can be assigned to a hopping algorithm. The base nodes under the branch node can follow the hoping algorithm applied to the branch node.

[0051] The base station 120a-120b can perform frequency hopping on a periodic basis, such as each frame, a number of frames, or some other predetermined number of OFDM symbols. As used herein, a frame refers to a predetermined structure of OFDM symbols, which may include one or more preamble symbols and one or more data symbols. The receiver can be configured to utilize the same frequency hopping algorithm to determine which sub-carriers are assigned to the SSCH or a corresponding data channel.

[0052] The base stations 120a-120b can modulate each of the sub-carriers assigned to the SSCH with the SSCH messages. The messages can include signaling messages and feedback messages. The signaling messages can include access grant messages, forward link assignment block messages, and reverse link block assignment messages. The feedback messages can include acknowledgement (ACK) messages and reverse link power control messages. The actual channels utilized in an SSCH may be all or some of the ones described above. Additionally, other channels may be included in SSCH in addition or in lieu of, any of the above channels.

[0053] The access grant message is used by the base station 120b to acknowledge an access attempt by an access terminal 110a and assign a Media Access Control Identification (MACID). The access grant message can also include an initial reverse link channel assignment. The sequence of modulation symbols corresponding to the access grant can be scrambled according to an index of the preceding access probe transmitted by the access terminal 110a. This scrambling enables the access terminal 110a to respond only to access grant blocks that correspond to the probe sequence that it transmitted.

[0054] **[0001]** The base station 120b can use the forward and reverse link access block messages to provide forward or reverse link sub-carrier assignments. The assignment messages can also include other parameters, such as modulation format, coding format, and packet format. The base station typically provides a channel

assignment to a particular access terminal 110a, and can identify the target recipient using an assigned MACID.

[0055] The base stations 120a-120b typically transmit the ACK messages to particular access terminals 110a-110b in response to successful receipt of a transmission. Each ACK message can be as simple as a one-bit message indicating positive or negative acknowledgement. An ACK message can be linked to each sub-carrier, e.g. by using related nodes in a channel tree to others for that access termina, or can be linked to a particular MACID. Further, the ACK messages may be encoded over multiple packets for the purposes of diversity.

[0056] The base stations 120a-120b can transmit reverse link power control messages to control the power density of reverse link transmissions from each of the access terminals 110a-110b. The base station 120a-120b can transmit the reverse power control message to command the access terminal 110a-110b to increase or decrease its power density.

[0057] The base stations 120a-120b can be configured to unicast each of the SSCH messages individually to particular access terminals 110a-110b. In unicast messaging, each message is modulated and power controlled independently from other messages. Alternatively, messages directed to a particular user can be combined and independently modulated and power controlled.

[0058] In another embodiment, the base stations 120a-120b can be configured to combine the messages for multiple access terminals 110a-110b and multi-cast the combined message to the multiple access terminals 110a-110b. In multicast, messages for multiple access terminals can be grouped in jointly encoded and power controlled sets. The power control for the jointly encoded messages needs to target the access terminal having the worst communication link. Thus, if the messages for two access terminals 110a and 110b are combined, the base station 120b sets the power control of the combined message to ensure that the access terminal 110a having the worst link receives the transmission. However, the level of power needed to ensure the worst communication link is satisfied may be substantially greater than required for an access terminal 110b at a close proximity to the base station 120b. Therefore, in some embodiments SSCH messages may be jointly encoded and power controlled for those

access terminals having substantially similar channel characteristics, e.g. SNRs, power offsets, etc.

[0059] In another embodiment, the base stations 120a-120b can group all of the message information for all access terminals 110a-110b served by a base station, for example 120b, and broadcast the combined message to all of the access terminals 110a-110b. In the broadcast approach, e all messages are jointly coded and modulated while power control targets the access terminal with the worst forward link signal strength.

[0060] Unicast signaling may be advantageous in those situations where multicast and broadcast require substantial power overhead to reach cell edge for a substantial number of bits. Unicast messages may benefit from power sharing between access terminals with different forward link signal strength through power control. Unicast messaging also benefits from the fact that many reverse link base nodes may not be assigned at any given point in time so that no energy needs to be expended reporting an ACK for those nodes.

[0061] From the MAC logic standpoint, unicast design enables the wireless communication system 100 to scramble ACK messages with the target MACID, preventing an access terminal that erroneously thinks that it is assigned the relevant resources targeted by the ACK (via assignment signaling errors such as missed de-assignment) from falsely interpreting the ACK that is actually intended for another MACID. Thus, such an access terminal will recover from the erroneous assignment state after a single packet since that packet cannot be positively acknowledged, and the access terminal will expire the erroneous assignment.

[0062] From the link performance standpoint, the main advantage of broadcast or multicast methods is coding gain due to joint encoding. However, the gain of power control exceeds substantially coding gain for practical geometry distributions. Also, unicast messaging can exhibit higher error rates compared to jointly encoded and CRC protected messages. However, practically achievable error rates of 0.01% to 0.1% are satisfactory.

[0063] It may be advantageous for the base stations 120a-120b to multicast or broadcast some messages while unicasting others. For example, an assignment message can be configured to automatically de-assigns resources from the access terminal that is

currently using resources corresponding to the sub-carriers indicated in the assignment message. Hence, assignment messages are often multicast since they target both the intended recipient of the assignment as well as any current users of the resources specified in the assignment message.

[0064] Figure 2 is a simplified functional block diagram of an embodiment of an OFDMA transmitter 200 such as can be incorporated within a base station of the wireless communication system of Figure 1. The transmitter 200 is configured to transmit one or more OFDMA signals to one or more access terminals. The transmitter 200 includes a SSCH module 230 configured to generate and implement a SSCH in the forward link.

[0065] The transmitter 200 includes a data buffer 210 configured to store data destined for one or more access terminals. The data buffer 210 can be configured, for example, to hold the data destined for each of the access terminals in a coverage area supported by the corresponding base station.

[0066] The data can be, for example, raw unencoded data or encoded data. Typically, the data stored in the data buffer 210 is unencoded, and is coupled to an encoder 212 where it is encoded according to a desired encoding rate. The encoder 212 can include encoding for error detection and Forward Error Correction (FEC). The data in the data buffer 210 can be encoded according to one or more encoding algorithms. Each of the encoding algorithms and resultant coding rates can be associated with a particular data format of a multiple format Hybrid Automatic Repeat Request (HARQ) system. The encoding can include, but is not limited to, convolutional coding, block coding, interleaving, direct sequence spreading, cyclic redundancy coding, and the like, or some other coding.

[0067] The encoded data to be transmitted is coupled to a serial to parallel converter and signal mapper 214 that is configured to convert a serial data stream from the encoder 212 to a plurality of data streams in parallel. The signal mapper 214 can determine the number of sub-carriers and the identity of the sub-carriers for each access terminal based on input provided by a scheduler (not shown). The number of carriers allocated to any particular access terminal may be a subset of all available carriers. Therefore, the signal mapper 214 maps data destined for a particular access terminal to

those parallel data streams corresponding to the data carriers allocated to that access terminal.

[0068] A SSCH module 230 is configured to generate the SSCH messages, encode the messages, and provide the encoded messages to the signal mapper 214. The SSCH module 230 can also provide the identity of the sub-carriers assigned to the SSCH. The SSCH module 230 can include a scheduler 252 configured to determine and assign nodes from a channel tree to the SSCH. The output of the scheduler 252 can be coupled to a frequency hopping module 254. The frequency hopping module 254 can be configured to map the assigned channel tree nodes determined by the scheduler 252 to the physical sub-carrier assignments. The frequency hopping module 254 can implement a predetermined frequency hopping algorithm.

[0069] The signal mapper 214 receives the SSCH message symbols and sub-carrier assignments, and maps the SSCH symbols to the appropriate sub-carriers. In one embodiment, the SSCH module 230 can be configured to generate a serial message stream and the signal mapper 214 can be configured to map the serial message to the assigned sub-carriers.

[0070] In one embodiment, the signal mapper 214 can be configured to interleave each modulation symbol from the SSCH message across all of the assigned sub-carriers. Interleaving the modulation symbols for the SSCH provides the SSCH signal with the maximum frequency and interference diversity.

[0071] The output of the serial to parallel converter/signal mapper 214 is coupled to a pilot module 220 that is configured to allocate a predetermined portion of the sub-carriers to a pilot signal. In one embodiment, the pilot signal can include a plurality of equally spaced sub-carriers spanning substantially the entire operating band. The pilot module 220 can be configured to modulate each of the carriers of the OFDMA system with a corresponding data or pilot signal.

[0072] Transmitting signaling blocks using the highest possible spectral efficiency is desirable to minimize bandwidth overhead of signaling messages. However, the downside of high spectral efficiency is the need for a higher energy per bit (E_b/N_0), which drives power overhead. Spectral efficiencies between 0.5bps/Hz and 1bps/Hz have been found to be a good compromise as they allow for a low bandwidth overhead

while achieving minimum (E_b/N_0) requirements. However, other spectral efficiencies may be suitable for some systems.

[0073] In one embodiment, the SSCH symbols are used to BPSK modulate the assigned sub-carriers. In another embodiment, the SSCH symbols are used to QPSK modulate the assigned sub-carriers. While practically any modulation type can be accommodated, it may be advantageous to use a modulation format that has a constellation that can be represented by a rotating phasor, because the magnitude does not vary as a function of the symbol. This may be beneficial because SSCH may then have different offsets but the same pilot references, and thereby be easier to demodulate.

[0074] The output of the pilot module 220 is coupled to an Inverse Fast Fourier Transform (IFFT) module 222. The IFFT module 222 is configured to transform the OFDMA carriers to corresponding time domain symbols. Of course, a Fast Fourier Transform (FFT) implementation is not a requirement, and a Discrete Fourier Transform (DFT) or some other type of transform can be used to generate the time domain symbols. The output of the IFFT module 222 is coupled to a parallel to serial converter 224 that is configured to convert the parallel time domain symbols to a serial stream.

[0075] The serial OFDMA symbol stream is coupled from the parallel to serial converter 224 to a transceiver 240. In the embodiment shown in Figure 2, the transceiver 240 is a base station transceiver configured to transmit the forward link signals and receive reverse link signals.

[0076] The transceiver 240 includes a forward link transmitter module 244 that is configured to convert the serial symbol stream to an analog signal at an appropriate frequency for broadcast to access terminals via an antenna 246. The transceiver 240 can also include a reverse link receiver module 242 that is coupled to the antenna 246 and is configured to receive the signals transmitted by one or more remote access terminals.

[0077] The SSCH module 230 is configured to generate the SSCH messages. As described earlier, The SSCH messages can include signaling messages. Additionally, the SSCH messages can include feedback messages, such as ACK messages or power control messages. The SSCH module 230 is coupled to the output of the receiver

module 242 and analyzes the received signals, in part, to generate the signaling and feedback messages.

[0078] The SSCH module 230 includes a signaling module 232, an ACK module 236, and a power control module 238. The signaling module 232 can be configured to generate the desired signaling messages and encode them according to the desired encoding. For example, the signaling module 232 can analyze the received signal for an access request and can generate an access grant message directed to the originating access terminal. The signaling module 232 can also generate and encode any forward link or reverse link block assignment messages.

[0079] Similarly, the ACK module 236 can generate ACK messages directed to access terminals for which a transmission was successfully received. The ACK module 236 can be configured to generate unicast, multicast, or broadcast messages, depending on the system configuration.

[0080] The power control module 238 can be configured to generate any reverse link power control messages based in part on the received signals. The power control module 238 can also be configured to generate the desired power control messages.

[0081] The power control module 238 can also be configured to generate the power control signals that control the power density of the SSCH messages. The SSCH module 230 can power control individual unicast messages based on the needs of the destination access terminal. Additionally, the SSCH module 230 can be configured to power control the multicast or broadcast messages based on the weakest forward link signal strength reported by the access terminals. The power control module 238 can be configured to scale the encoded symbols from each of the modules within the SSCH module 230. In another embodiment, the power control module 238 can be configured to provide control signals to the pilot module 220 to scale the desired SSCH symbols. The power control module 238 thus allows the SSCH module 230 to power control each of the SSCH messages according to its needs. This results in reduced power overhead for the SSCH.

[0082] Figure 3 is a simplified time-frequency diagram 300 of an embodiment of a shared signaling channel, such a channel generated by the SSCH module of the transmitter of Figure 2. The time frequency diagram 300 details the SSCH sub-carrier

allocation for two successive frames, 310 and 320. The two successive frames 310 and 320 can represent the successive frames of an FDM system of a TDM system, although the successive frames in a TDM system may have one or more intervening frames allocated to reverse link access terminal transmissions (not shown).

[0083] The first frame 310 includes three frequency bands, 312a-312c, that can be representative of three separate sub-carriers assigned to the SSCH in the particular frame. The three sub-carrier assignments 312a-312c are shown as maintained over the entire duration of the frame 310. In some embodiments, the sub-carrier assignments can change during the course of the frame 310. The number of times that the sub-carrier assignments can change during the course of a frame 310 is defined by the frequency hopping algorithm, and is typically less than the number of OFDM symbols in the frame 310.

[0084] In the embodiment shown in Figure 3, the sub-carrier assignment changes on the frame boundary. The second, successive frame 320 also includes the same number of sub-carriers assigned to the SSCH as in the first frame 310. In one embodiment, the number of sub-carriers assigned to the SSCH is predetermined and fixed. For example, the SSCH bandwidth overhead can be fixed to some predetermined level. In another embodiment, the number of sub-carriers assigned to the SSCH is variable, and can be assigned by a system control message. Typically, the number of sub-carriers assigned to the SSCH does not vary at a high rate.

[0085] The sub-carriers mapped to the SSCH can be determined by a frequency hopping algorithm that maps a logical node assignment to a physical sub-carrier assignment. In the embodiment shown in Figure 3, the three sub-carrier physical assignments 322a-322c are different in the second, successive frame 320. As before, the embodiment depicts the sub-carrier assignments as stable for the entire length of the frame 320.

[0086] Figure 4 is a simplified flowchart of an embodiment of a method 400 of generating shared signaling channel messages. The transmitter having the SSCH module as shown in Figure 2 can be configured to perform the method 400. The method 400 depicts the generation of one frame of SSCH messages. The method 400 can be repeated for additional frames.

[0087] The method 400 begins at block 410 where the SSCH module generates the signaling messages. The SSCH module can generate signaling messages in response to requests. For example, the SSCH module can generate access grant messages in response to access requests. Similarly, the SSCH module can generate forward link or reverse link assignment block messages in response to a link request or a request to transmit data.

[0088] The SSCH module proceeds to block 412 and encodes the signaling messages. The SSCH can be configured to generate unicast messages for particular message types, for example access grants. The SSCH module can be configured to identify a MACID of a destination access terminal when formatting a unicast message. The SSCH module can encode the message and can generate a CRC code and append the CRC to the message. Additionally, the SSCH can be configured to combine the messages for several access terminals into a single multicast or broadcast message and encode the combined messages. The SSCH can, for example, include a MACID designated for broadcast messages. The SSCH can generate a CRC for the combined message and append the CRC to the encoded messages.

[0089] The SSCH module can proceed to block 414 to power control the signaling messages. In one embodiment, the SSCH can adjust or otherwise scale the amplitude of the encoded messages. In another embodiment, the SSCH module can direct a modulator to scale the amplitude of the symbols.

[0090] The SSCH module then performs similar steps for the generation of ACK and reverse link power control feedback messages. At block 420, the SSCH module generates the desired ACK messages based on received access terminal transmissions. The SSCH module proceeds to block 420 and encodes the ACK messages, for example, as unicast messages. The SSCH module proceeds to block 424 and adjusts the power of the ACK symbols.

[0091] The SSCH module proceeds to block 430 and generates reverse link power control messages based, for example, on the received signal strength of each individual access terminal transmission. The SSCH module proceeds to block 432 and encodes the power control messages, typically as unicast messages. The SSCH module proceeds to block 434 and adjusts the power of the reverse link power control message symbols.

[0092] The SSCH proceeds to block 440 and determines which nodes from a logical structure, such as a channel tree, are assigned to the SSCH. The SSCH module proceeds to block 450 and maps the physical sub-carrier assignment to the assigned nodes. The SSCH module can use a frequency hopper algorithm to map the logical node assignment to the sub-carrier assignment. The frequency hopper algorithm can be such that the same node assignment can produce different physical sub-carrier assignments for different frames. The frequency hopper can thus provide a level of frequency diversity, as well as some level of interference diversity.

[0093] The SSCH proceeds to block 460 and maps the message symbols to the assigned sub-carriers. The SSCH module can be configured to interleave the message symbols among the assigned sub-carriers to introduce diversity to the signal.

[0094] The symbols modulate the OFDM sub-carriers, and the modulated sub-carriers are transformed to OFDM symbols that are transmitted to the various access terminals. The SSCH module allows a fixed bandwidth FDM channel to be used for signaling and feedback messages while allowing flexibility in the amount of power overhead that is dedicated to the channel.

[0095] Figure 5 is a simplified flowchart of another embodiment of a method 500 of generating shared signaling channel messages. The method 500 can be implemented, for example, by the transmitter having the SSCH module shown in Figure 2.

[0096] The method 500 begins at block 510 where the transmitter assigns a predetermined bandwidth to the SSCH. The transmitter can assign a number of sub-carriers of a set of OFDM sub-carriers that is substantially equal to the predetermined bandwidth. For example, the transmitter can assign approximately 10% of the available bandwidth to the SSCH.

[0097] The transmitter proceeds to block 520 and assigns resources to the SSCH based on the predetermined bandwidth. In one embodiment, the transmitter can be configured to assign resources from a based on a logical resource model, such as a channel tree. The channel tree can be organized as a number of branches that split at nodes until reaching a final base node, alternatively referred to as a leaf node. The transmitter can assign the resources by assigning one or more nodes to the SSCH. After assigning the nodes from the channel tree, the transmitter can map the logical nodes to

the physical sub-carriers in the OFDM system. The transmitter can assign the nodes based on a logical model in a system where the physical mapping can change over time. For example, the transmitter can implement frequency hopping in the sub-carriers of the SSCH. The transmitter can maintain the initial logical node assignment and can determine the physical sub-carrier mapping based on a predetermined frequency hopping algorithm.

[0098] The transmitter proceeds to block 530 and generates the messages that are to be carried over the SSCH. The messages can be nearly any type of signaling or overhead message. For example, the messages can include channel assignment messages directed to access terminals, ACK messages, and reverse link power control messages, as well as other types of overhead messages. The messages can be directed to individual access terminals or can be directed to multiple access terminals. In one embodiment, some or all of the messages can be broadcast messages that are directed to all access terminals within the coverage area served by the SSCH.

[0099] After generating the messages, the transmitter proceeds to block 540 and encodes the messages. The messages can be combined and jointly encoded, with a single CRC generated for the combined message. In another embodiment, some of the messages can be unicast messages each directed to a single access terminal and the message can include a CRC based on the unicast message contents. The SSCH messages can include a combination of combined and unicast messages. The transmitter encodes the messages to generate SSCH symbols. In one embodiment, each symbol is configured as a modulation symbol for a corresponding sub-carrier.

[00100] The transmitter proceeds to block 550 and adjusts the power density associated with each encoded message. In the case of a unicast message, the transmitter can adjust the power density of the message based on the quality of the communication link between the transmitter and the desired access terminal. In the case of a multicast or broadcast message, the transmitter can adjust the power density of the message based on the worst communication link, which typically corresponds to an access terminal at an edge of the coverage area supported by the SSCH.

[00101] The transmitter proceeds to block 560 and modulates the assigned resources with the message symbols. In one embodiment, the transmitter interleaves the message

symbols across the assigned sub-carriers by mapping the symbols of a message to an assigned sub-carrier in a round-robin fashion. The transmitter modulates the sub-carrier with the message symbol.

[00102] In one embodiment, the transmitter can modulate the sub-carriers using distinct modulation formats based on the message. For example, the transmitter can modulate signaling messages, such as forward link and reverse link block assignment messages using a first modulation format, and can modulate ACK messages or some other message, using a second modulation format. The transmitter can implement various modulation formats, including but not limited to, On-Off-Keying, Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), or some other modulation format.

[00103] The transmitter proceeds to block 570 and transforms the sub-carriers to OFDM symbols. In one embodiment, the modulation and sub-carrier transformation can be performed by the same module. In other embodiments, the modulation and transformation are distinct. The transmitter can, for example, implement an IFFT module that maps the total set of OFDM sub-carriers to an equivalent sized set of time domain symbols.

[00104] The transmitter proceeds to block 580 and transmits the OFDM symbols that include the SSCH. The transmitter can, for example, upconvert the OFDM symbols to a predetermined operating band prior to transmitting the OFDM symbols.

[00105] Methods and apparatus for generating a shared signaling channel (SSCH) for an OFDMA wireless communication system have been described herein. The SSCH can be an FDM channel that is assigned a predetermined bandwidth. The predetermined bandwidth establishes an overhead bandwidth used by the SSCH. The overhead bandwidth can be fixed by fixing the number of sub-carriers assigned to the SSCH.

[00106] It should be noted that the concept of channels herein refers to information or transmission types that may be transmitted by the access point or access terminal. It does not require or utilize fixed or predetermined blocks of subcarriers, time periods, or other resources dedicated to such transmissions.

[00107] The power overhead used by the SSCH can be variable. The messages within the SSCH can be power controlled to a level necessary to satisfy a link requirement.

The SSCH messages can be unicast messages and the power of the unicast messages can be controlled to a level dictated by the communication link to the desired access terminal. When multicast or broadcast messages are included, the SSCH can control the power of the combined message to satisfy the worst case communication link experienced by the destination access terminals. The FDM SSCH configuration allows much greater flexibility in the power resources that need to be allocated to support the channel.

[00108] The various illustrative logical blocks, modules, and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), a Reduced Instruction Set Computer (RISC) processor, an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, but in the alternative, the processor may be any processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, for example, a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[00109] The steps of a method, process, or algorithm described in connection with the embodiments disclosed herein may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two.

[00110] A software module may reside in RAM memory, flash memory, non-volatile memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An exemplary storage medium is coupled to the processor such the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. Further, the various methods may be performed in the order shown in the embodiments or may be performed using a modified order of steps. Additionally, one or more process or method steps may be omitted or one or more process or method steps may be added to the methods and

processes. An additional step, block, or action may be added in the beginning, end, or intervening existing elements of the methods and processes.

[00111] The above description of the disclosed embodiments is provided to enable any person of ordinary skill in the art to make or use the disclosure. Various modifications to these embodiments will be readily apparent to those of ordinary skill in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of the disclosure. Thus, the disclosure is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

WHAT IS CLAIMED IS:

1. A method of generating signaling channel messages in a wireless communication system including a plurality of sub-carriers spanning an at least a portion of an operating frequency band, the method comprising:

assigning resources corresponding to a predetermined bandwidth allocated to a signaling channel;

generating at least one message;

encoding the at least one message to generate at least one message symbol;

controlling a power density of the at least one message symbol; and

modulating at least a portion of the resources allocated to the signaling channel.

2. The method of claim 1, further comprising:

transforming the plurality of sub-carriers, including at least one sub-carrier within the predetermined bandwidth allocated to the signaling channel, to an OFDM symbol; and

transmitting the OFDM symbol over a wireless communication link.

3. The method of claim 1, wherein assigning resources comprises:

determining a number of sub-carriers from the plurality of sub-carriers corresponding to the predetermined bandwidth; and

assigning a subset of the plurality of sub-carriers equal to the number of sub-carriers to the signaling channel.

4. The method of claim 1, wherein assigning resources comprises:

assigning a set of logical resources corresponding to the predetermined bandwidth to the signaling channel; and

mapping the set of logical resources to a corresponding subset of the plurality of sub-carriers.

5. The method of claim 4, wherein mapping the set of logical resources comprises mapping the set of logical resources to the corresponding subset of the plurality of sub-carriers based in part on a frequency hopping algorithm.

6. The method of claim 1, wherein generating at least one message comprises generating at least one access grant message directed to a particular access terminal.

7. The method of claim 6, wherein the at least one access grant message comprises a MACID corresponding to the particular access terminal.

8. The method of claim 1, wherein generating at least one message comprises generating at least one link assignment block message directed to a plurality of access terminals.

9. The method of claim 8, wherein the at least one link assignment block message comprises a broadcast MACID.

10. The method of claim 1, wherein generating at least one message comprises generating at least one acknowledgement (ACK) message in response to a received transmission from an access terminal.

11. The method of claim 1, wherein generating at least one message comprises generating at least one reverse power link control message directed to a particular access terminal.

12. The method of claim 1, wherein encoding the at least one message comprises:

generating a Cyclic Redundancy Code (CRC) corresponding to a single message; and

appending the CRC to the single message.

13. The method of claim 1, wherein encoding the at least one message comprises:

aggregating multiple messages to generate a combined message;

encoding the combined message; and

appending the combined message with a Cyclic Redundancy Check (CRC) corresponding to the combined message.

14. The method of claim 1, wherein modulating at least the portion of the resources comprises:

modulating a first sub-carrier allocated to the signaling channel with a first message symbol from the at least one message symbol; and

modulating a second sub-carrier allocated to the signaling channel with a second message symbol from the at least one message symbol.

15. The method of claim 1, wherein modulating at least the portion of the resources comprises interleaving the at least one message symbol across at least two sub-carriers allocated to the signaling channel.

16. A method of generating signaling channel messages in a wireless communication system including a plurality of sub-carriers spanning at least a portion of an operating frequency band, the method comprising:

generating at least one message;

encoding the at least one message to generate a plurality of message symbols;

adjusting a power density associated with the plurality of message symbols;

determining a subset of sub-carriers assigned to a signaling channel from the plurality of sub-carriers; and

modulating each of the subset of sub-carriers with at least one symbol from the plurality of message symbols.

17. The method of claim 16, wherein generating at least one message comprises generating a unicast message directed to a particular access terminal.

18. The method of claim 16, wherein generating at least one message comprises generating a multicast message directed to a particular group of access terminals.

19. The method of claim 16, wherein generating at least one message comprises generating a broadcast message directed to any access terminal within a coverage area served by the signaling channel.

20. The method of claim 16, further comprising;
transforming the plurality of sub-carriers to an OFDM symbol; and
transmitting the OFDM symbol over a wireless channel.

21. An apparatus configured to generate signaling channel messages in a wireless communication system including a plurality of sub-carriers spanning at least a portion of an operating frequency band, the apparatus comprising:

a scheduler configured to assign a subset of the plurality of sub-carriers to a signaling channel;

a signaling module configured to generate at least one signaling message;

a power control module configured to adjust a power density of the at least one signaling message; and

a signal mapper coupled to the scheduler and the signaling module and configured to map symbols from the at least one signaling message to the subset of the plurality of sub-carriers.

22. The apparatus of claim 21, wherein the scheduler is configured to assign the subset of the plurality of sub-carriers based in part on a frequency hopping algorithm.

23. The apparatus of claim 21, wherein the scheduler is configured to assign a fixed number of sub-carriers from the plurality of sub-carriers.

24. The apparatus of claim 21, wherein the at least one signaling message comprises a broadcast signaling message directed to a plurality of access terminals.

25. The apparatus of claim 21, wherein the at least one signaling message comprises a unicast signaling message directed to a particular access terminal identified by a corresponding MACID.

26. The apparatus of claim 21, wherein the power control module is configured to adjust an amplitude of each symbol from the at least one signaling message.

27. The apparatus of claim 21, further comprising an Inverse Fast Fourier Transform (IFFT) module coupled to the signal mapper and configured to transform the plurality of sub-carriers to time domain OFDM symbols.

28. An apparatus configured to generate signaling channel messages in a wireless communication system including a plurality of sub-carriers spanning at least a portion of an operating frequency band, the apparatus comprising:

means for generating at least one message;

means for encoding the at least one message to generate a plurality of message symbols;

means for adjusting a power density associated with the plurality of message symbols;

means for determining a subset of sub-carriers assigned to a signaling channel from the plurality of sub-carriers; and

means for modulating each of the subset of sub-carriers with at least one symbol from the plurality of message symbols.

29. The apparatus of claim 28, wherein the means for generating the at least one message comprises a means for generating a broadcast signaling message.

30. The apparatus of claim 28, wherein the means for generating the at least one message comprises a means for generating a unicast acknowledgement message.

31. The apparatus of claim 28, wherein the means for generating the at least one message comprises a means for generating a unicast reverse link power control message.

32. The apparatus of claim 28, wherein the means for determining the subset of sub-carriers assigned to the signaling channel comprises means for determining the subset of sub-carriers based in part on a frequency hopping algorithm.

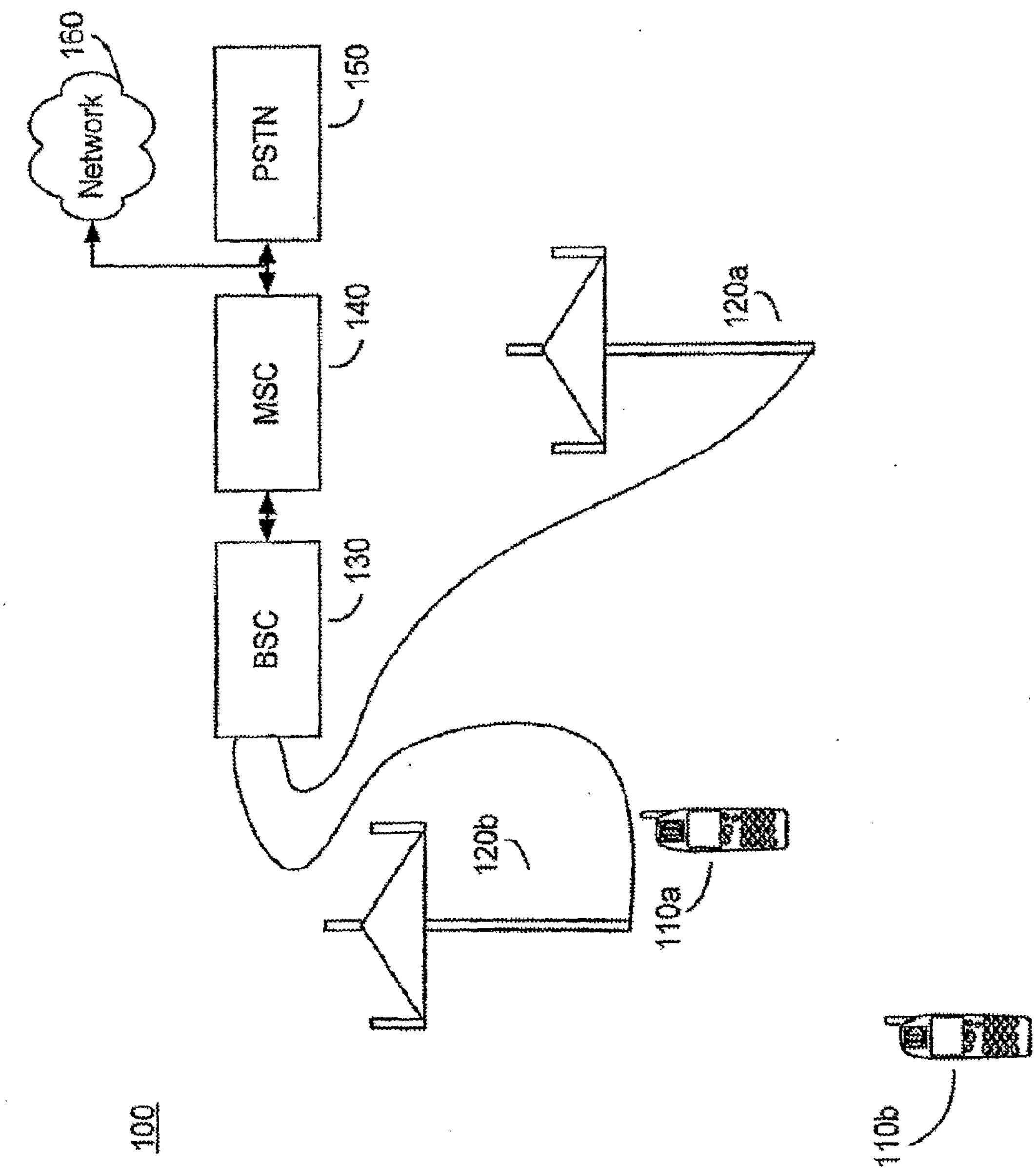

FIG. 1

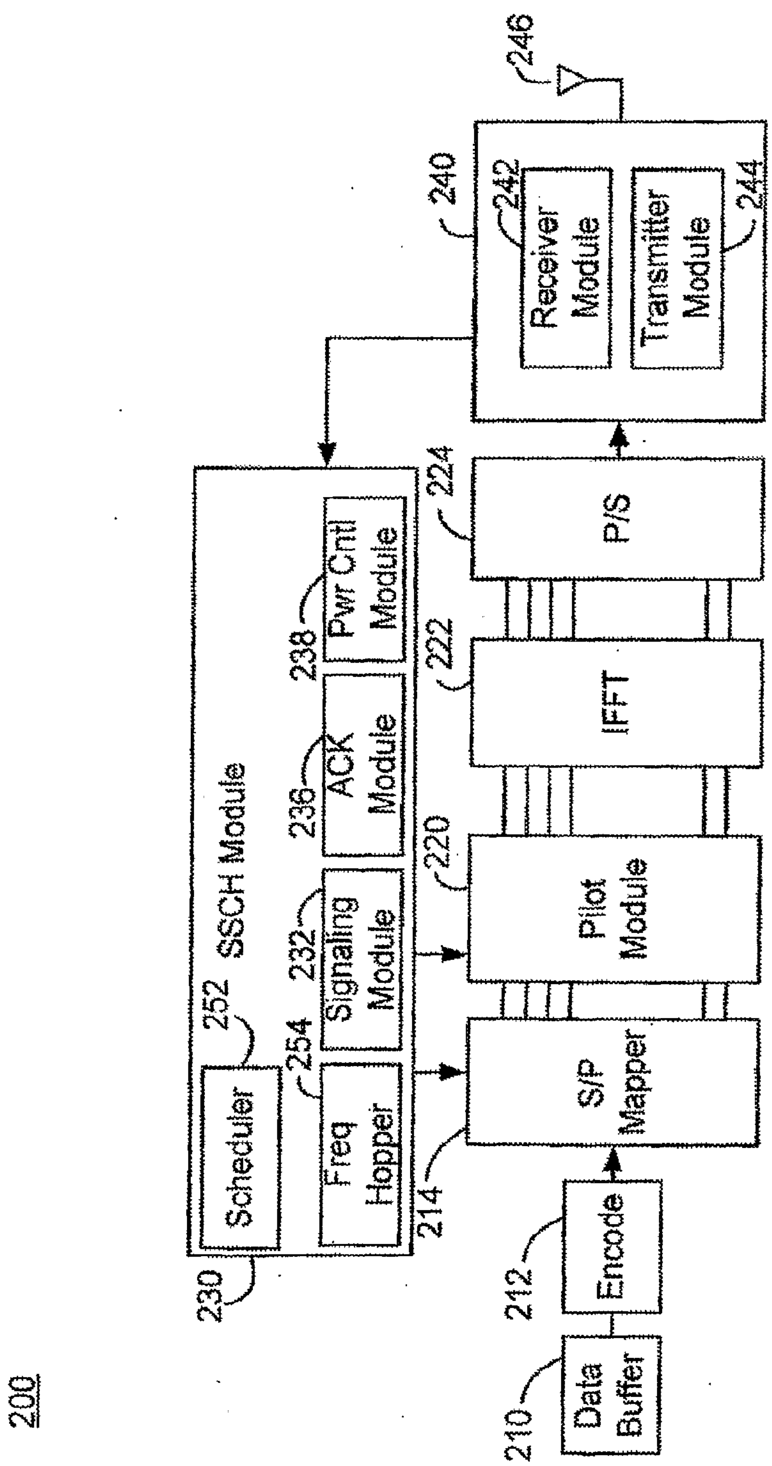
200
210
Data Buffer
212
Encode
214
S/P Mapper
220
Pilot Module
222
IFFT
224
P/S
230
SSCH Module
Scheduler
252
254
Freq Hopper
232
Signaling Module
236
ACK Module
238
Pwr Cntl Module
240
242
Receiver Module
Transmitter Module
244
246

FIG. 2

3/5

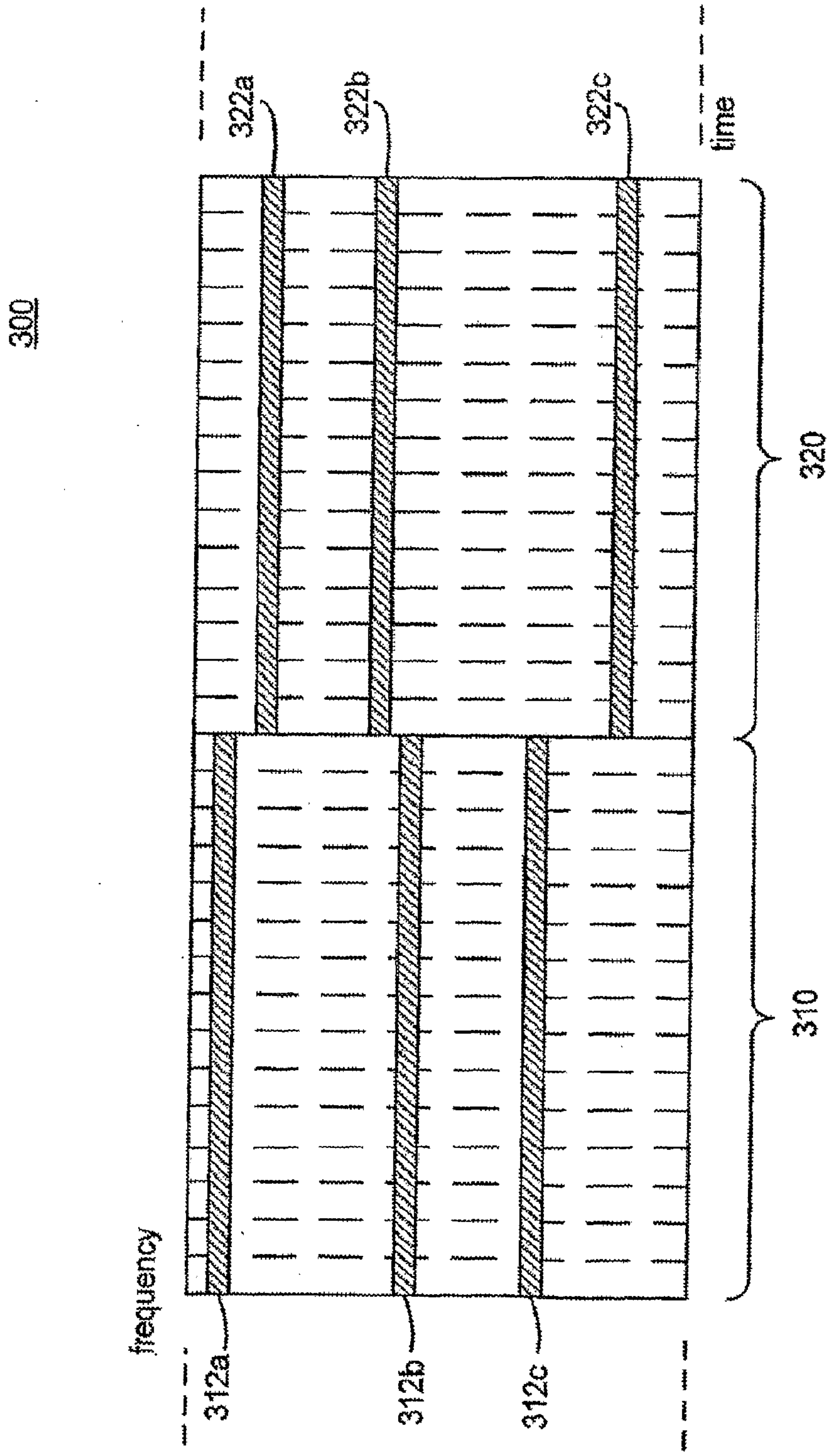

FIG. 3

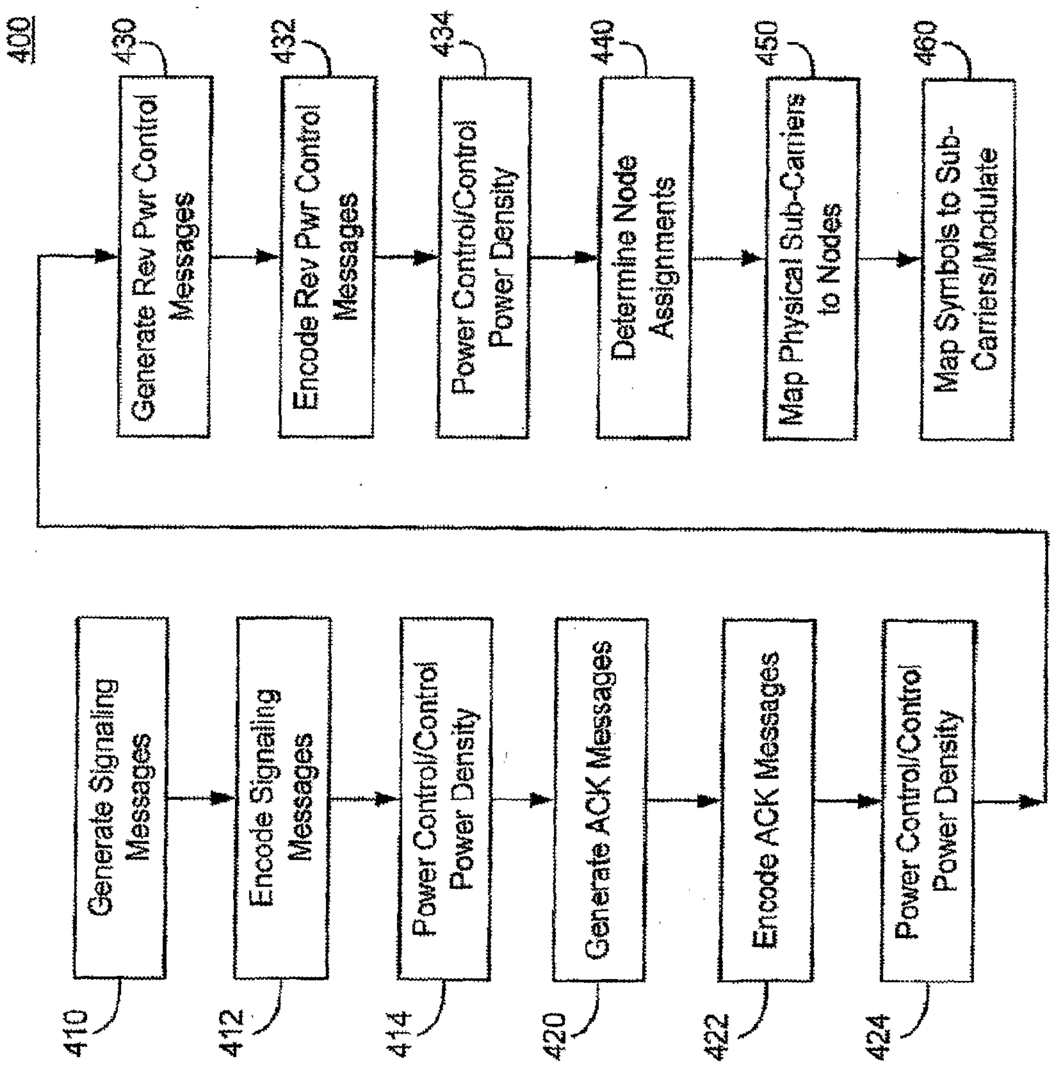
400
Generate Signaling Messages
410
Encode Signaling Messages
412
Power Control/Control Power Density
414
Generate ACK Messages
420
Encode ACK Messages
422
Power Control/Control Power Density
424
Generate Rev Pwr Control Messages
430
Encode Rev Pwr Control Messages
432
Power Control/Control Power Density
434
Determine Node Assignments
440
Map Physical Sub-Carriers to Nodes
450
Map Symbols to Sub-Carriers/Modulate
460

FIG. 4

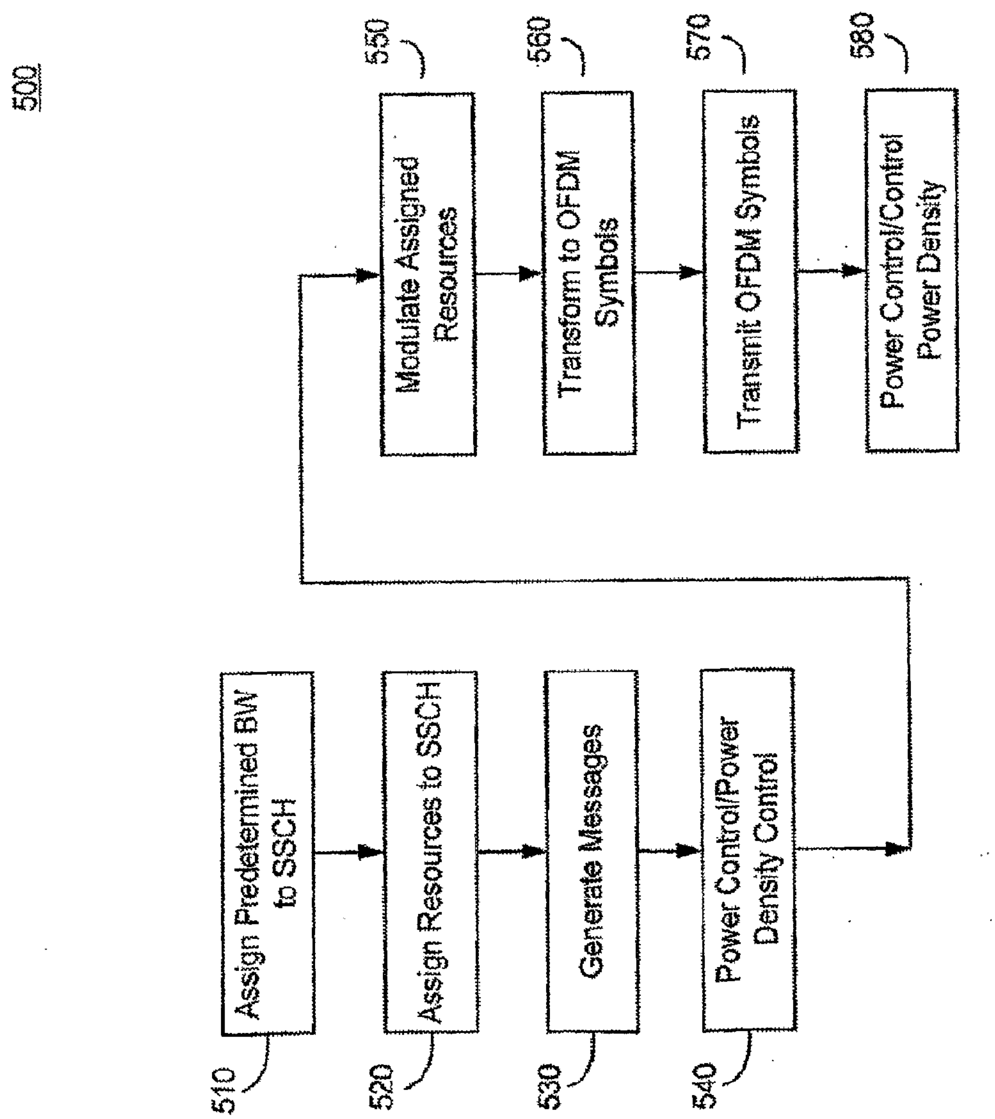
500
510
Assign Predetermined BW to SSCH
520
Assign Resources to SSCH
530
Generate Messages
540
Power Control/Power Density Control
550
Modulate Assigned Resources
560
Transform to OFDM Symbols
570
Transmit OFDM Symbols
580
Power Control/Control Power Density

FIG. 5